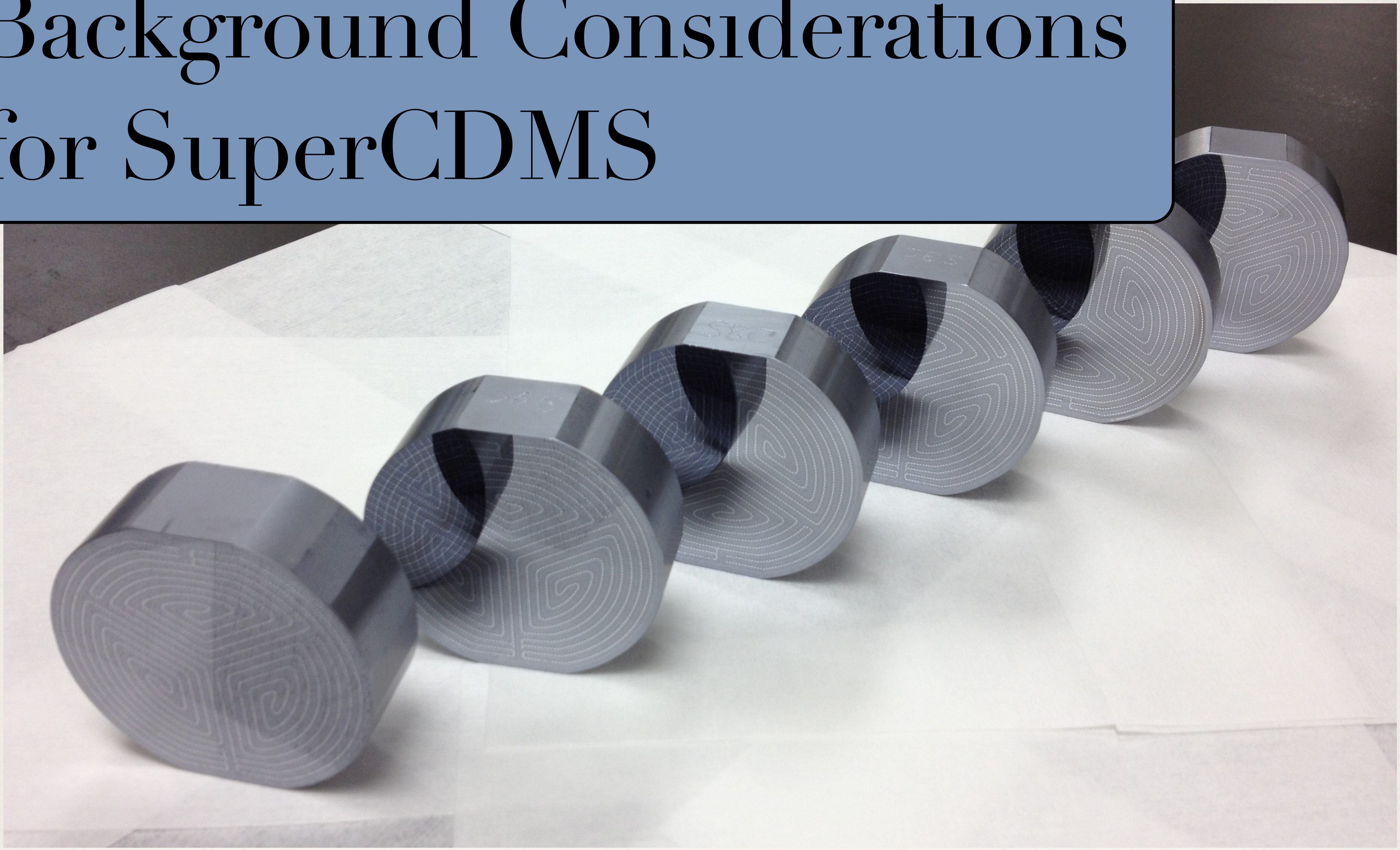
Background Considerations for SuperCDMS



Jodi Cooley - SuperCDMS
Southern Methodist University

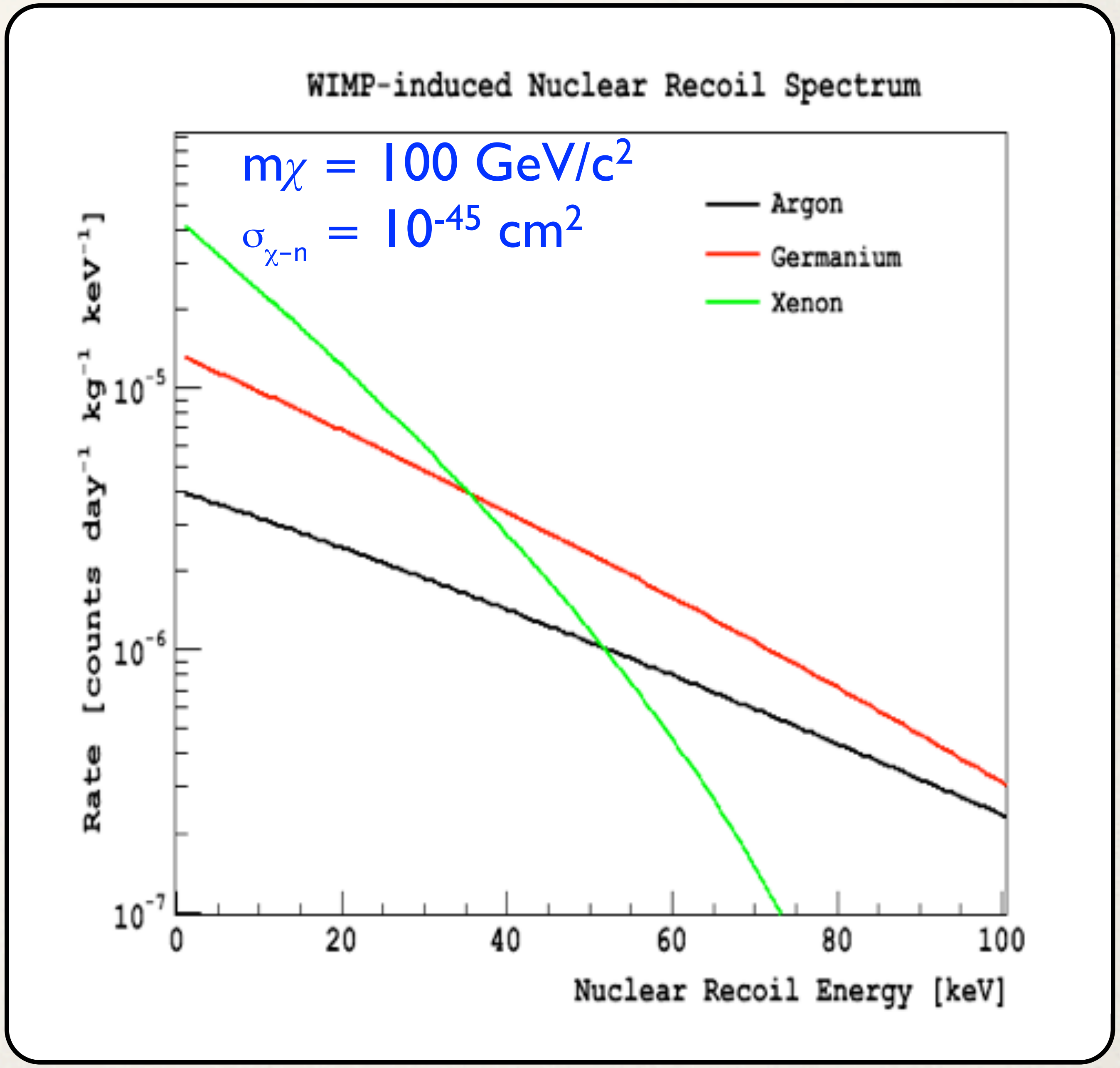
SuperCDMS Collaboration

- California Institute of Technology
- Fermi National Accelerator Laboratory
- Massachusetts Institute of Technology
- NIST
- Pacific Northwest National Laboratory
- Queen's University
- Santa Clara University
- SLAC/KIPAC
- Southern Methodist University*
- Stanford University
- Syracuse University
- Texas A&M
- University of British Colombia
- University of California, Berkeley
- University of California, Santa Barbara
- University of Colorado, Denver
- University of Evansville
- University of Florida
- FT-UAM/CSIC and Universidad Autonoma de Madrid
- University of Minnesota

*The SMU SuperCDMS group is supported by the NSF under grant number 1151869.

Direct Detection Event Rates

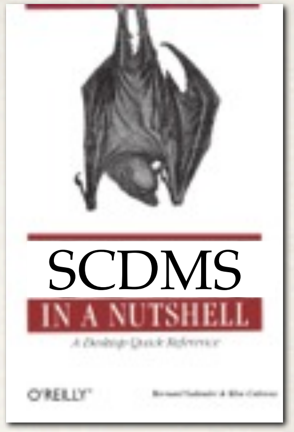
- **Elastic scattering** of a WIMP deposits small amounts of energy into recoiling nucleus (~ few 10s of keV)
- Featureless **exponential spectrum**
- **Expected rate:** **< 5 interaction per ton per day (3.8 x 10^{-44} cm^2 for m_χ = 70 GeV)**
- Background caused by the radioactivity of most materials is higher than this rate!



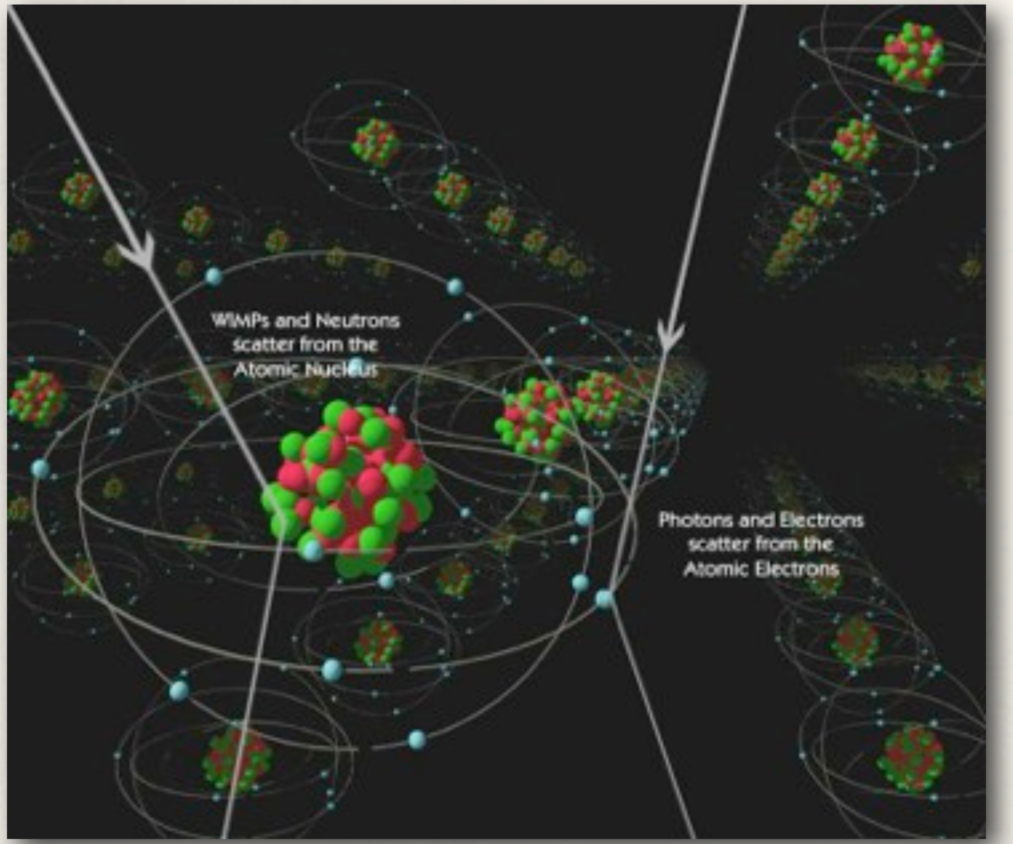
Challenges

- ✓ **Low energy thresholds** (~10 keV)
- ✓ Rigid **background controls**
  - ➡ Clean materials
  - ➡ shielding
  - ➡ discrimination power
- ✓ Substantial **Depth**
  - ➡ neutrons look like WIMPS
- ✓ **Long exposures**
  - ➡ large masses, long term stablility

The Big Picture



Use a combination of **discrimination** and **shielding** to maintain a **"<1 event expected background"** experiment with **low temperature** semiconductor detectors



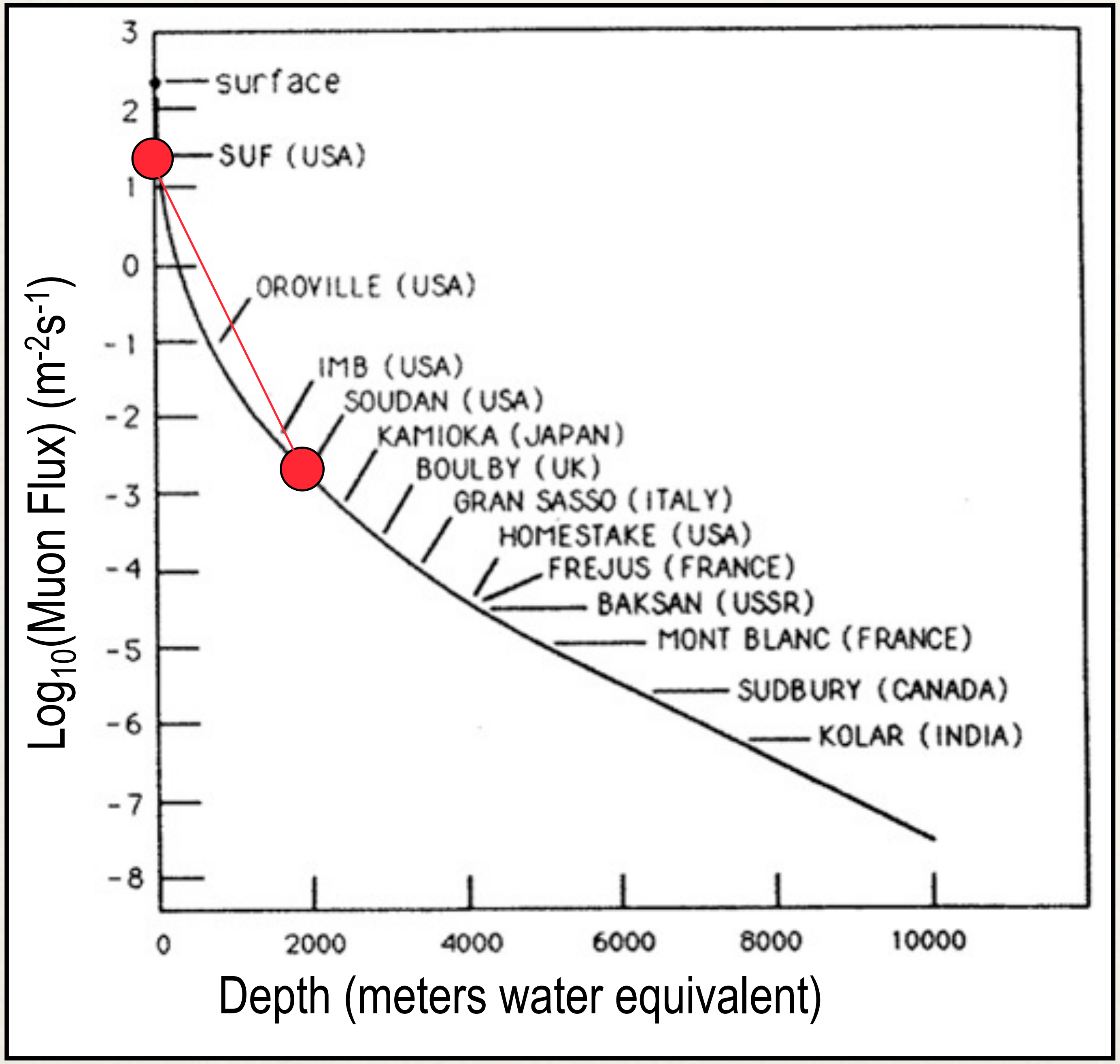
Primary Backgrounds:
Photons, Electrons and Neutrons.

Discrimination from measurements of **ionization** and **phonon energy**.

Keep backgrounds low as possible through shielding and material selection.


LEVEL NO. 27
2341 FEET BELOW THE SURFACE
689 FEET BELOW SEA LEVEL

Depth is Important!



mwe = meters water equivalent

SUF *(CDMS I)*

17 mwe

0.5 n/d/kg

(182.5 n/y/kg)

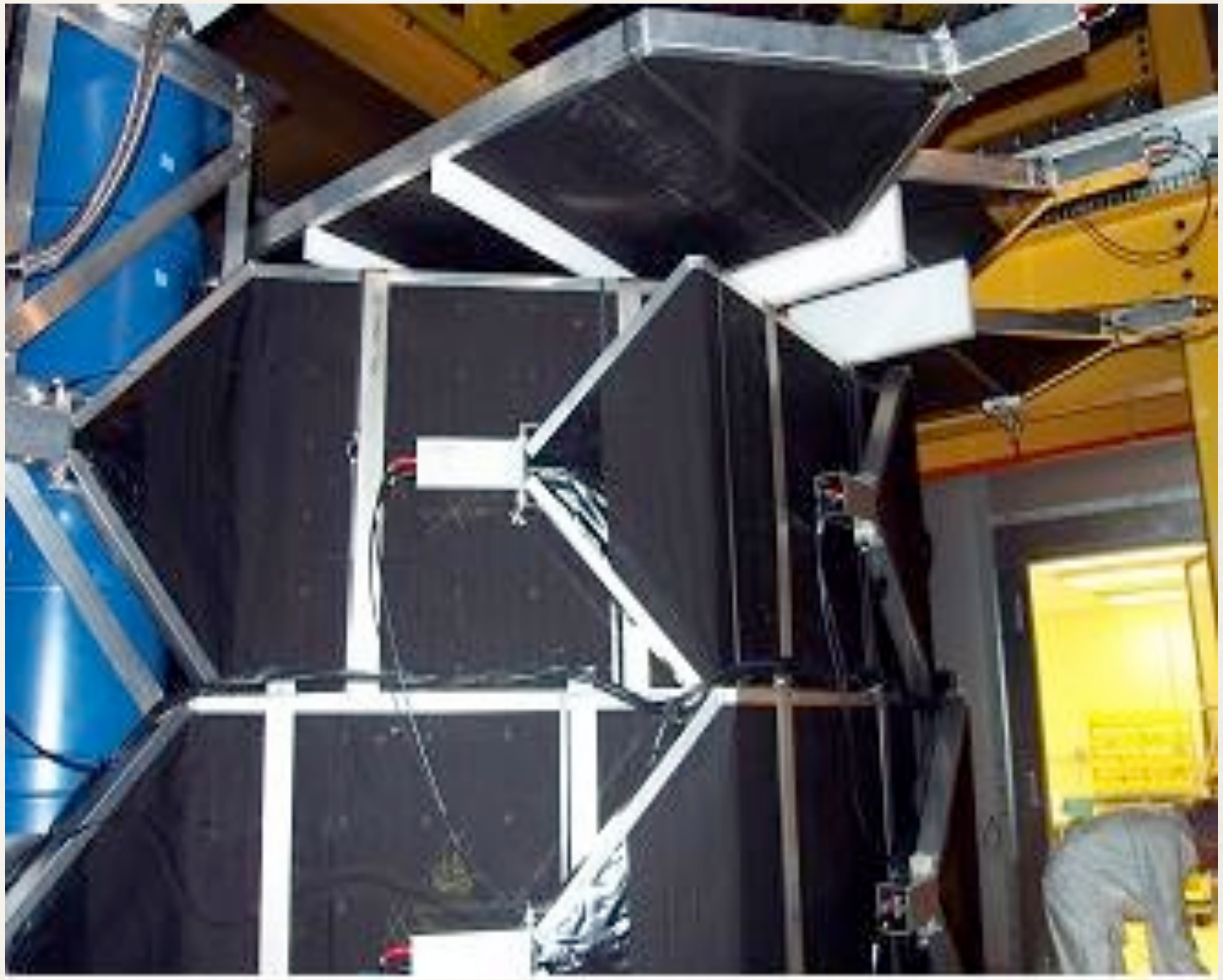
Soudan *(CDMS II, SuperCDMS)*

2090 mwe

0.05 n/y/kg

Shielding

Active Muon Veto:
rejects events from cosmic rays



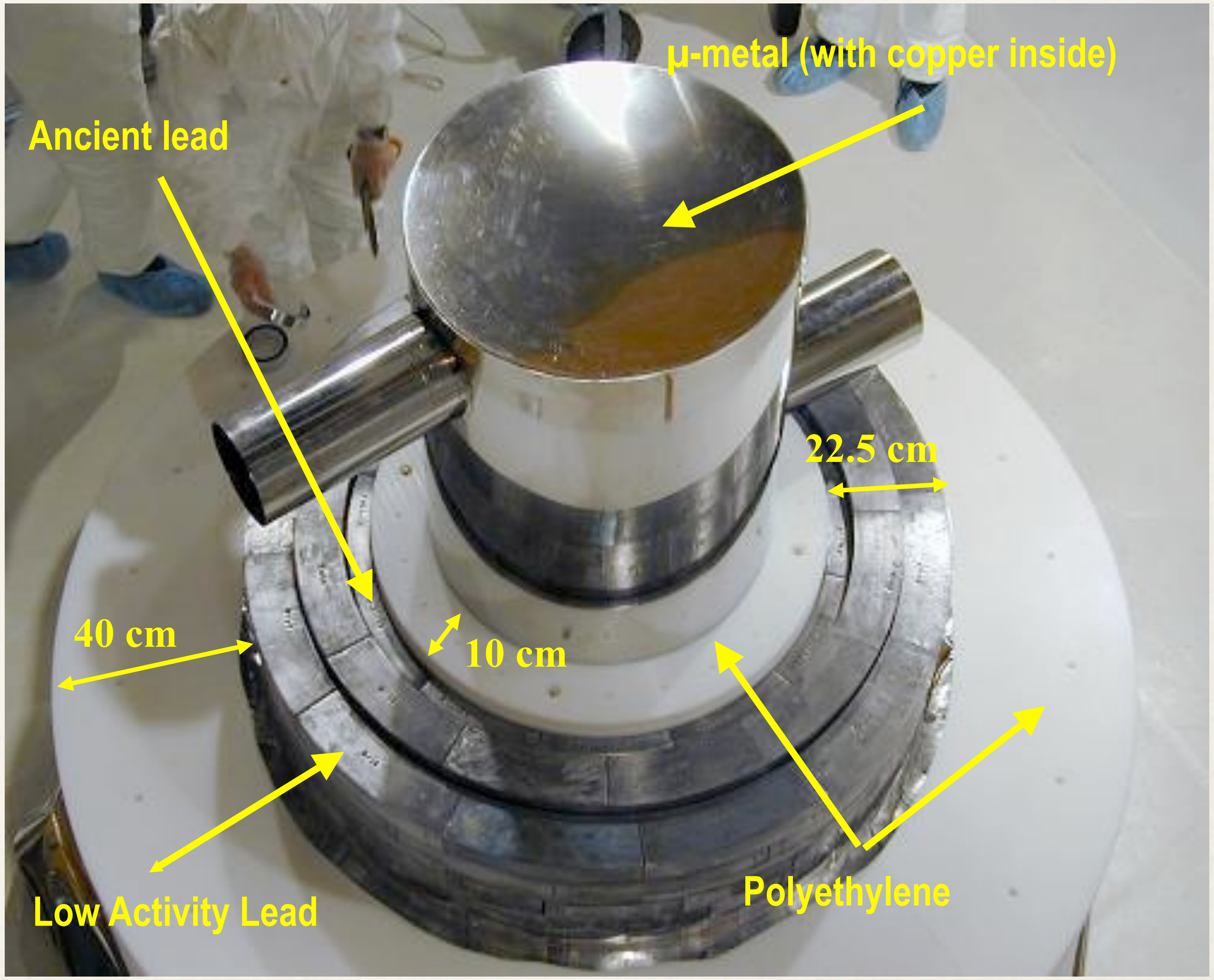
CDMS active muon veto

Shielding - An Example

Active Muon Veto: rejects events from cosmic rays

Pb: shielding from gammas resulting from radioactivity

Polyethyene: moderate neutrons produced from fission decays and from (α,n) interactions resulting from U/Th decays



CDMS - Layers of Polyethylene and Lead

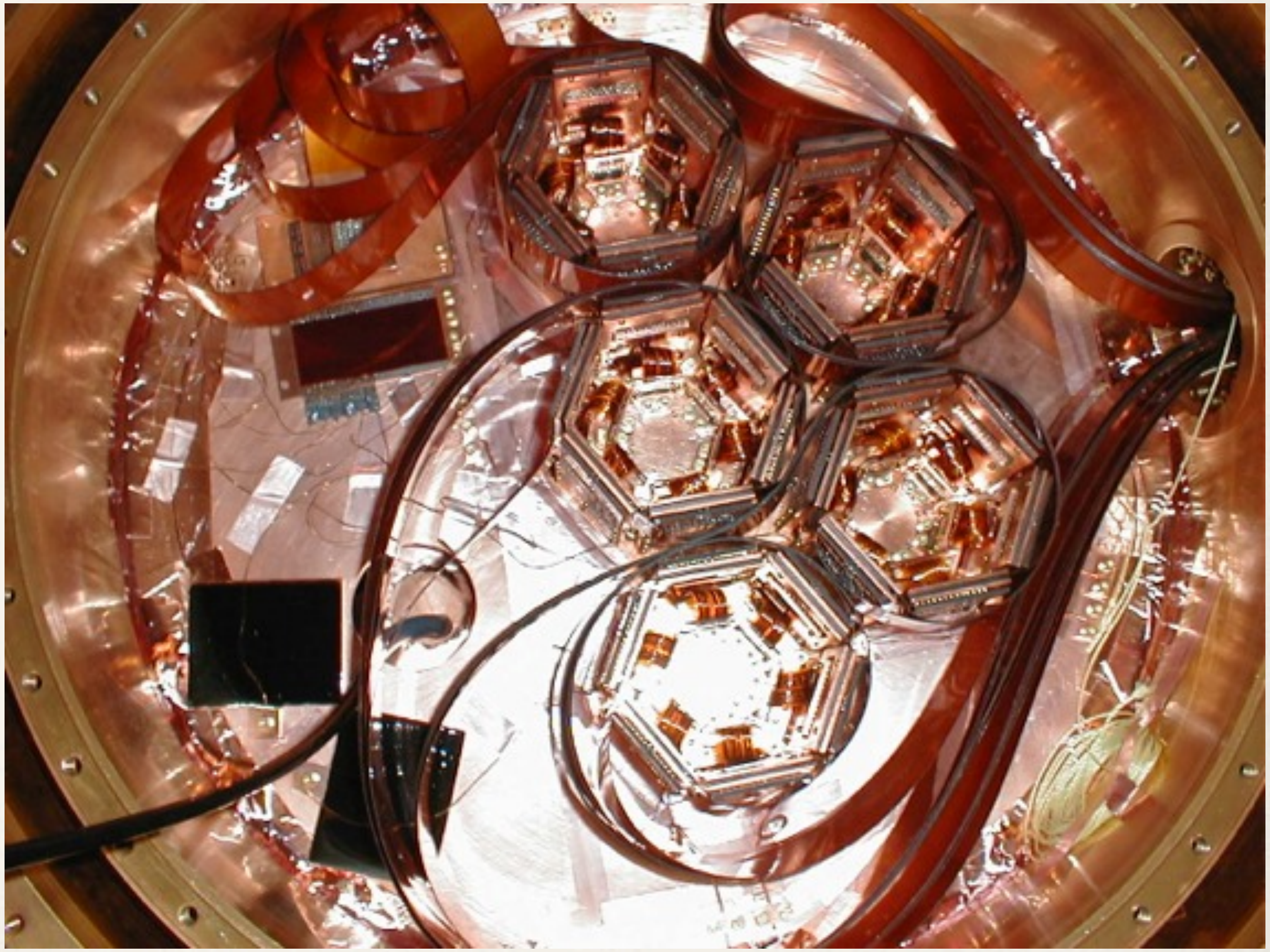
Shielding

Active Muon Veto: rejects events from cosmic rays

Pb: shielding from gammas resulting from radioactivity

Polyethyene: moderate neutrons produced from fission decays and from (α,n) interactions resulting from U/Th decays

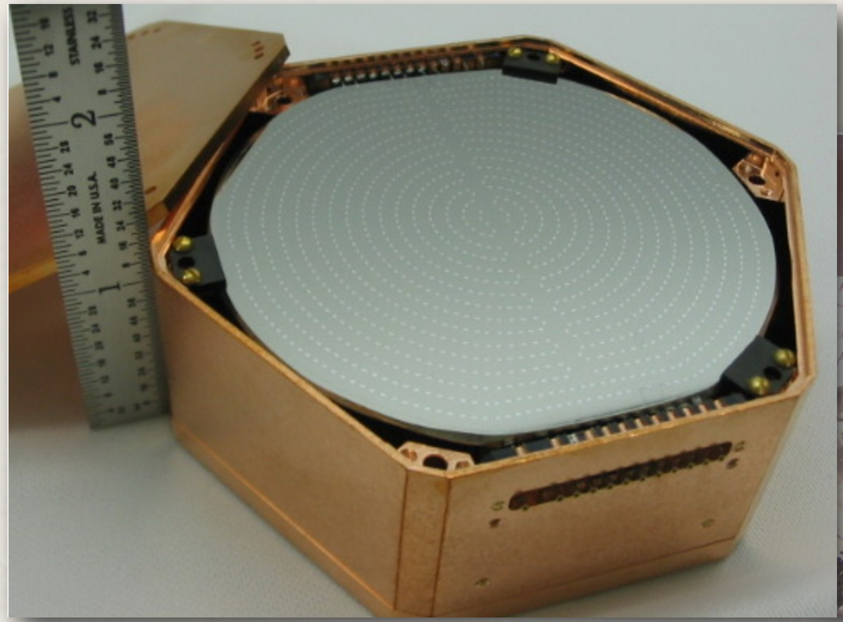
Cu: shielding from gammas

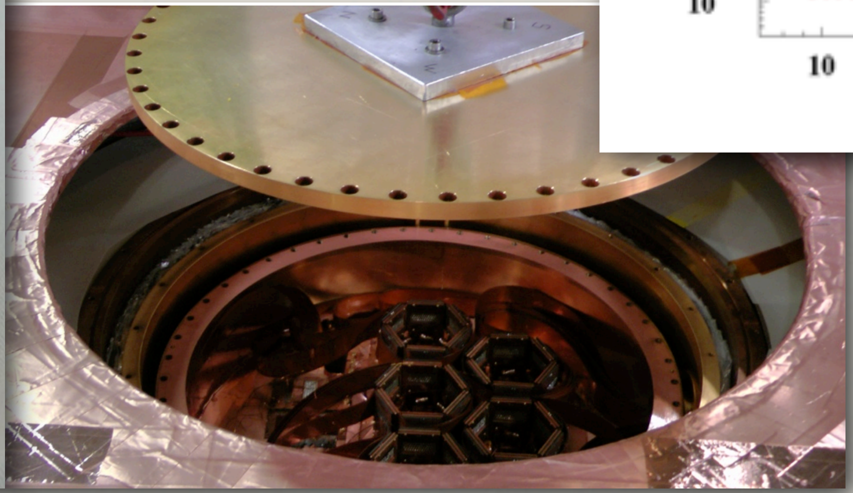


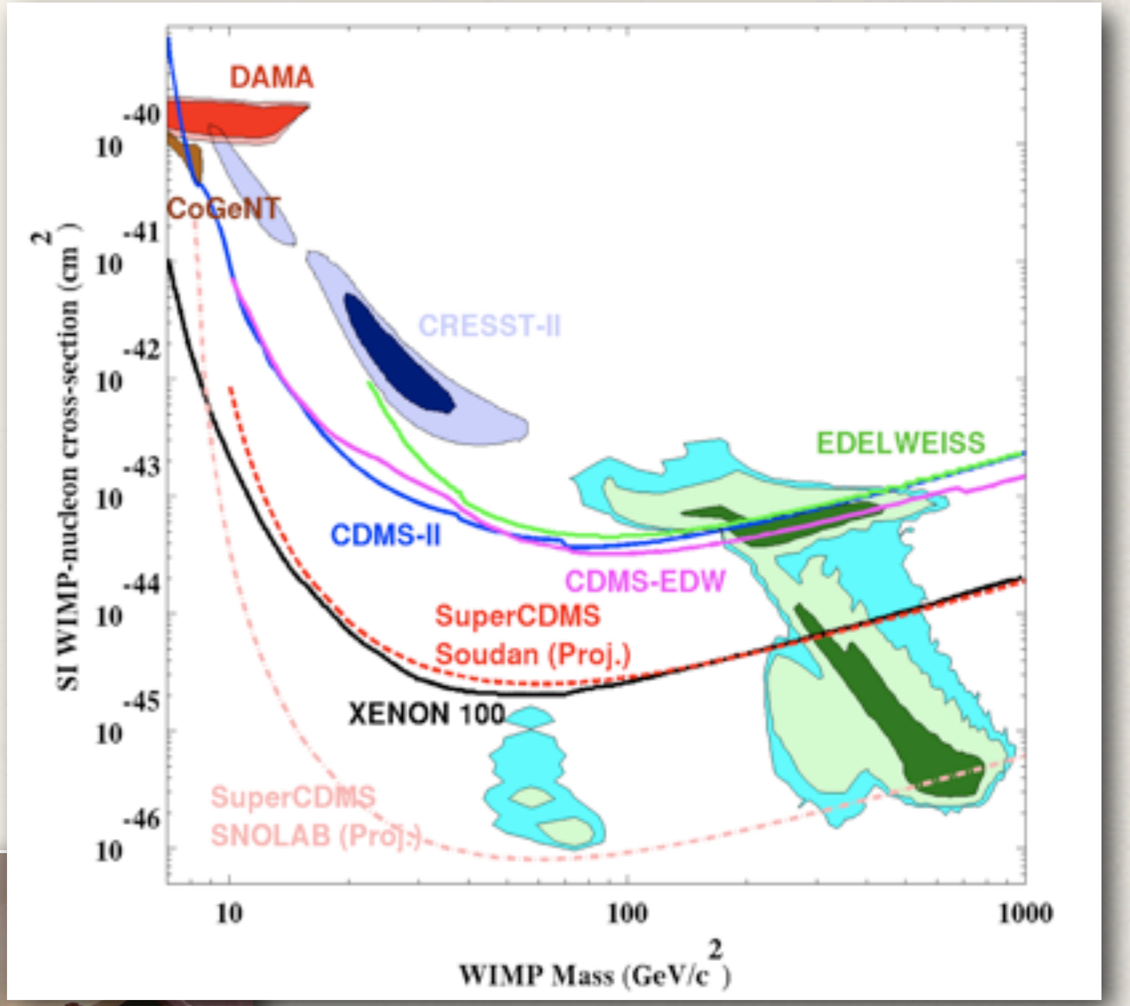
CDMS - Top view of inner most shield layer

SuperCDMS at Soudan

- Currently operating 5 towers of of advanced iZIP detectors (~9 kg Ge) in the existing cryostat at the Soudan Underground Laboratory.
- After 3 years of operation, expected to improve sensitivity to spin-independent WIMP-nucleon interactions by a factor of ~10 over existing CDMS II results.

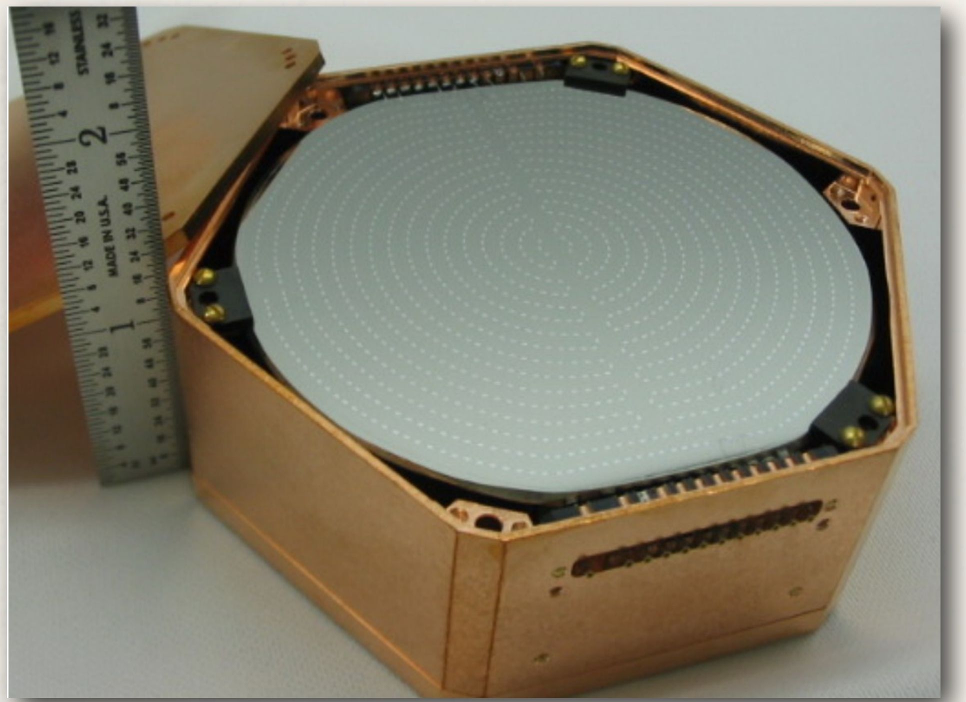


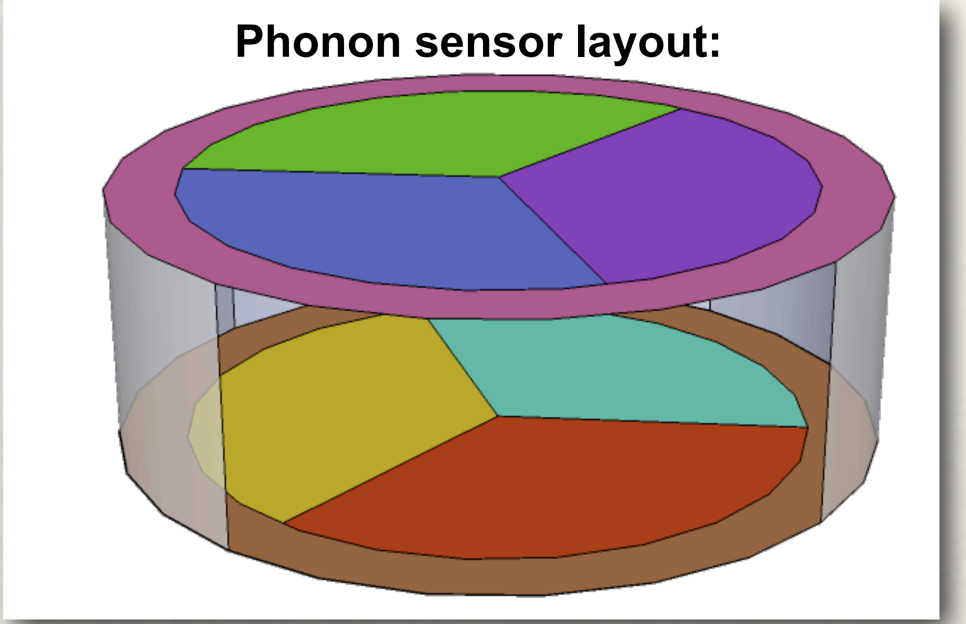




Installation complete Nov. 8, 2011. Operating with final detector settings since Mar. 2012.

The Detectors





- 76 x 25 mm interleaved ZIP (iZIP) double sided detectors
  - (2.5x thicker than CDMS II)
- Ionization electrodes are interleaved with narrow strips of phonon sensors.
  - Phonon sensors optimized to enhance phonon signal to noise ratio
- Optimized sensor layout
  - Each side has one outer channel to reject zero charge events and 3 inner channels to reject surface events.
- Ionization channels can be used to reject surface events

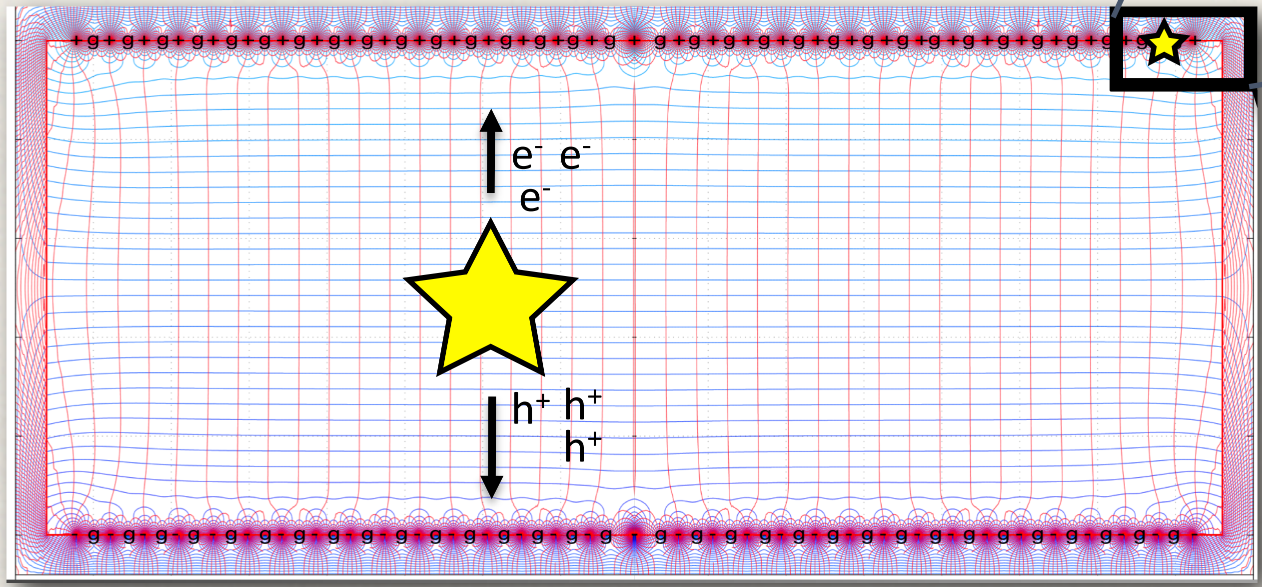
SuperCDMS iZIPs: Charge Signal

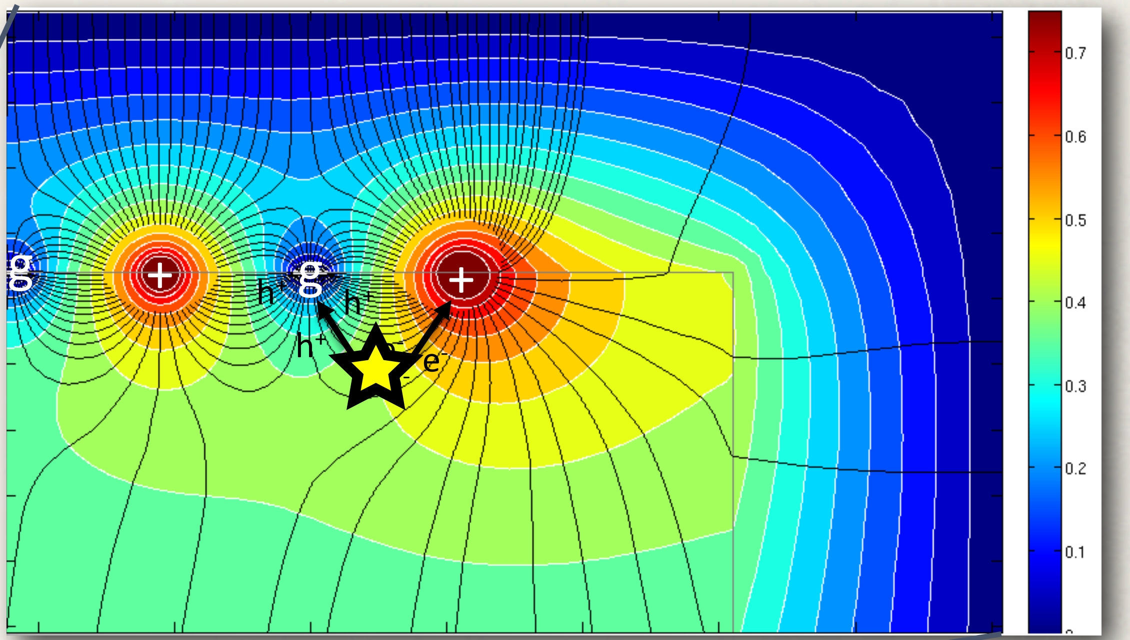
Bulk Events:

Equal but opposite ionization signal appears on both sides of detector (symmetric)

Surface Events:

Ionization signal appears on one detector side (asymmetric)





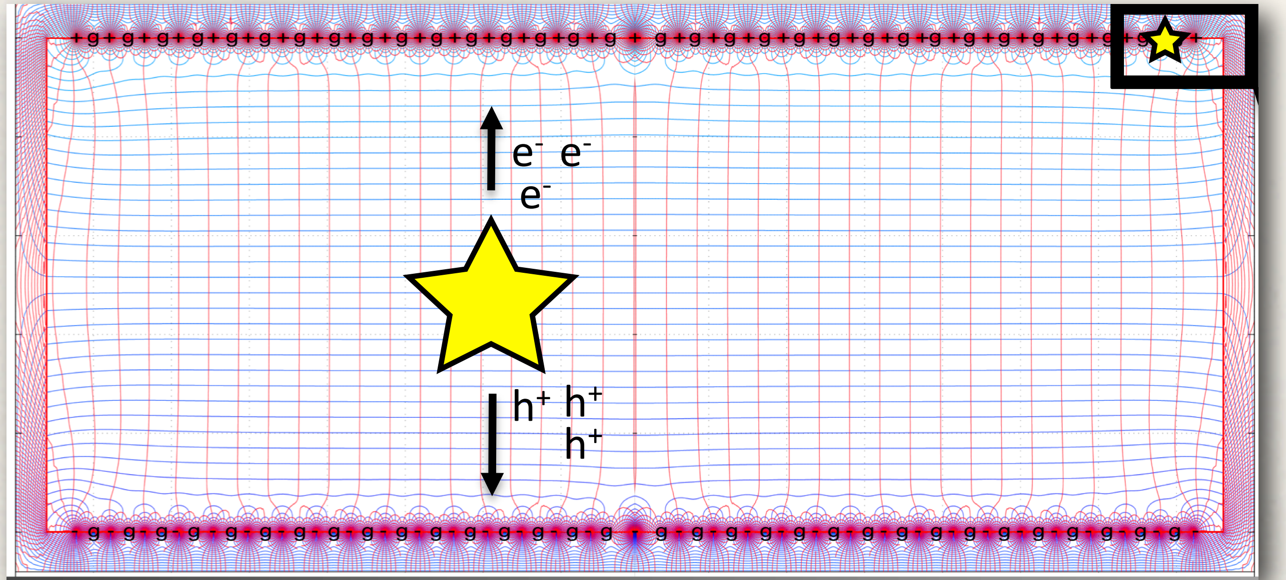
SuperCDMS iZIPs: Ionization Signal

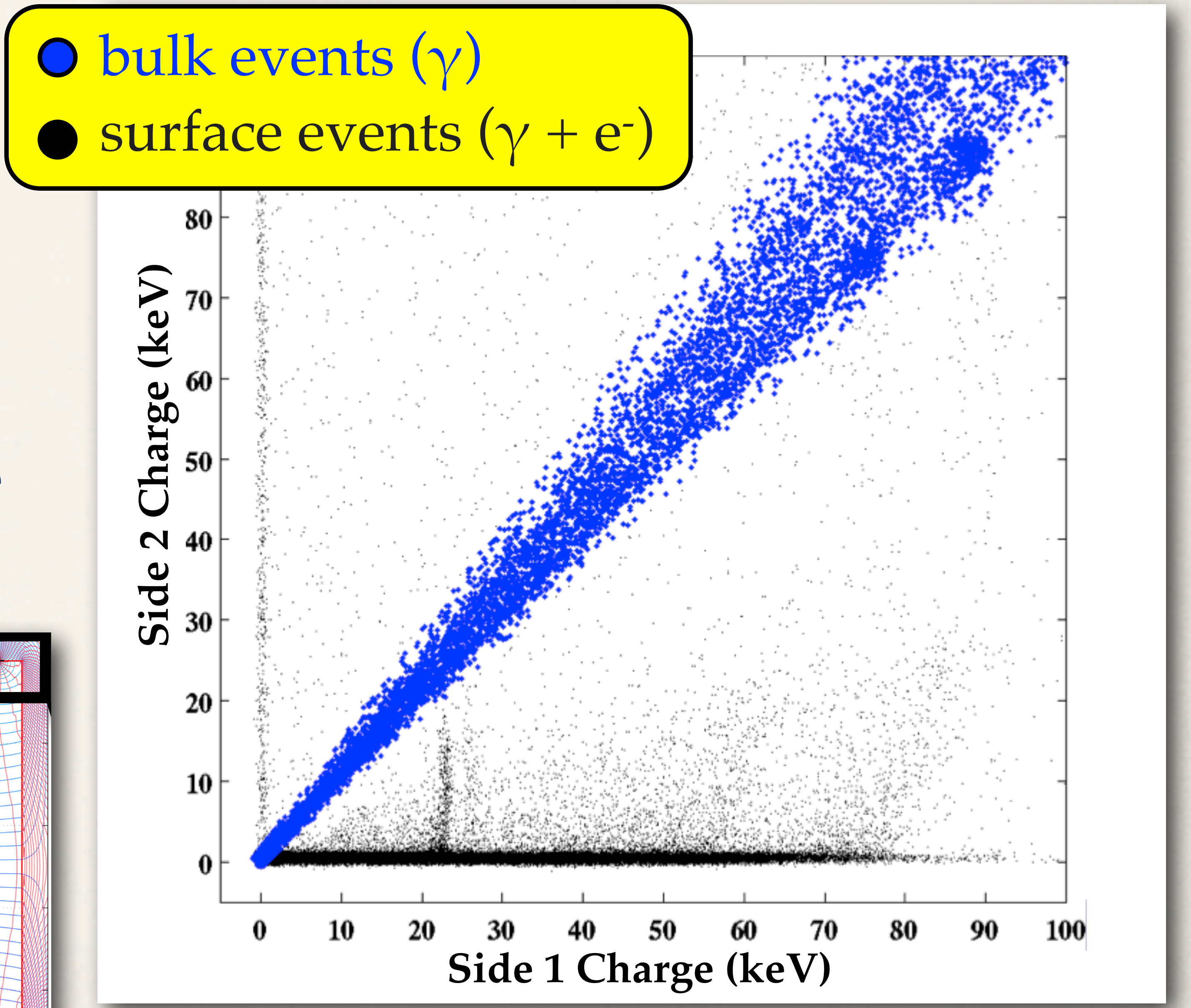
Bulk Events:

Equal but opposite ionization signal appears on both sides of detector (symmetric)

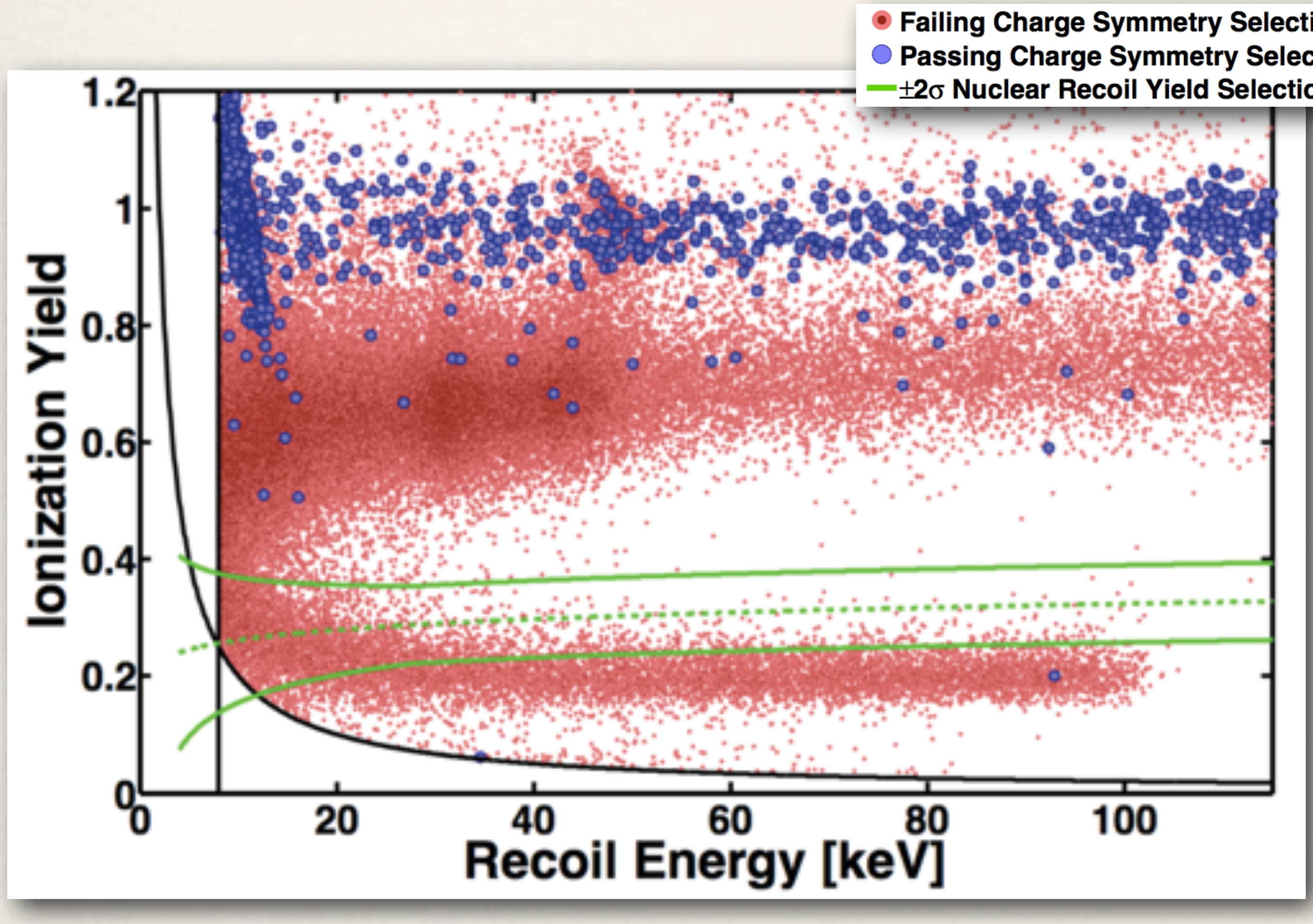
Surface Events:

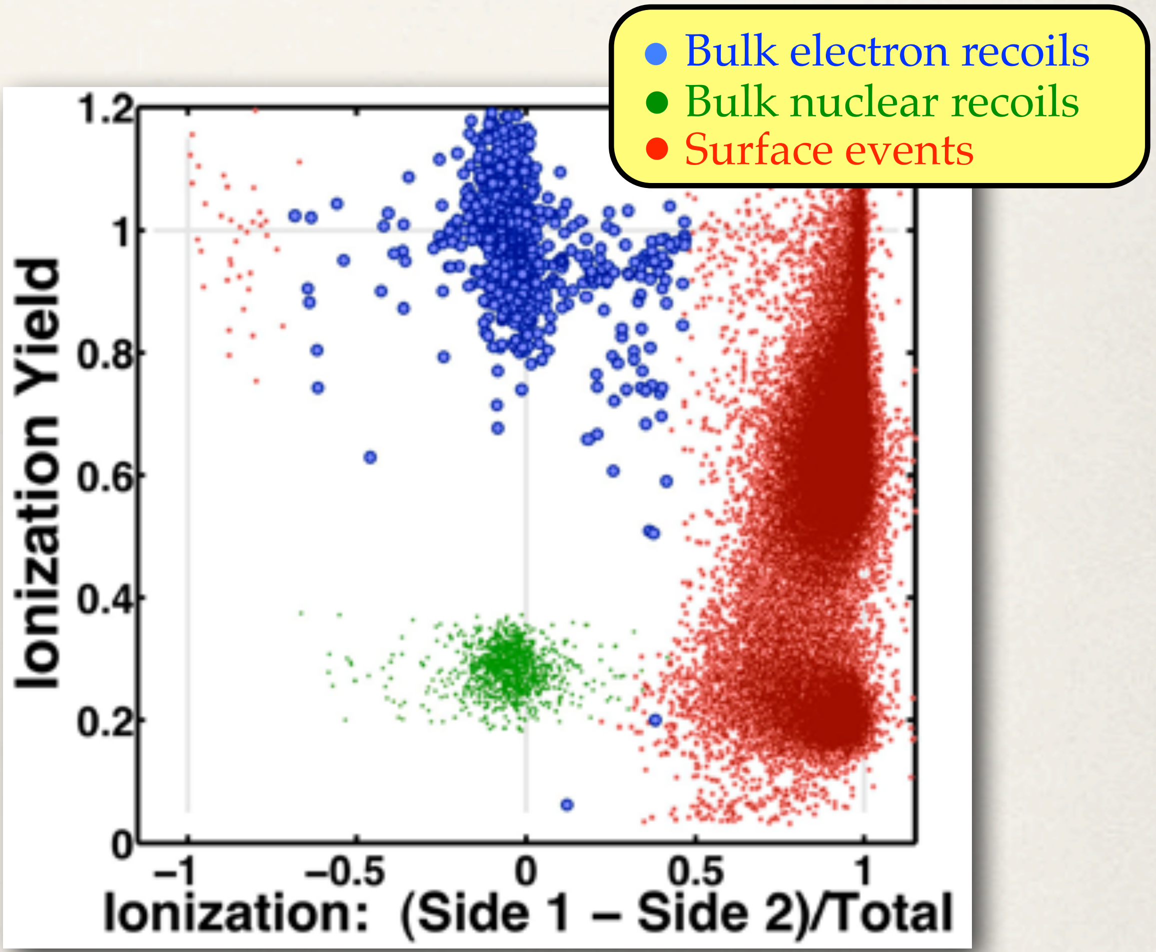
Ionization signal appears on one detector side (asymmetric)





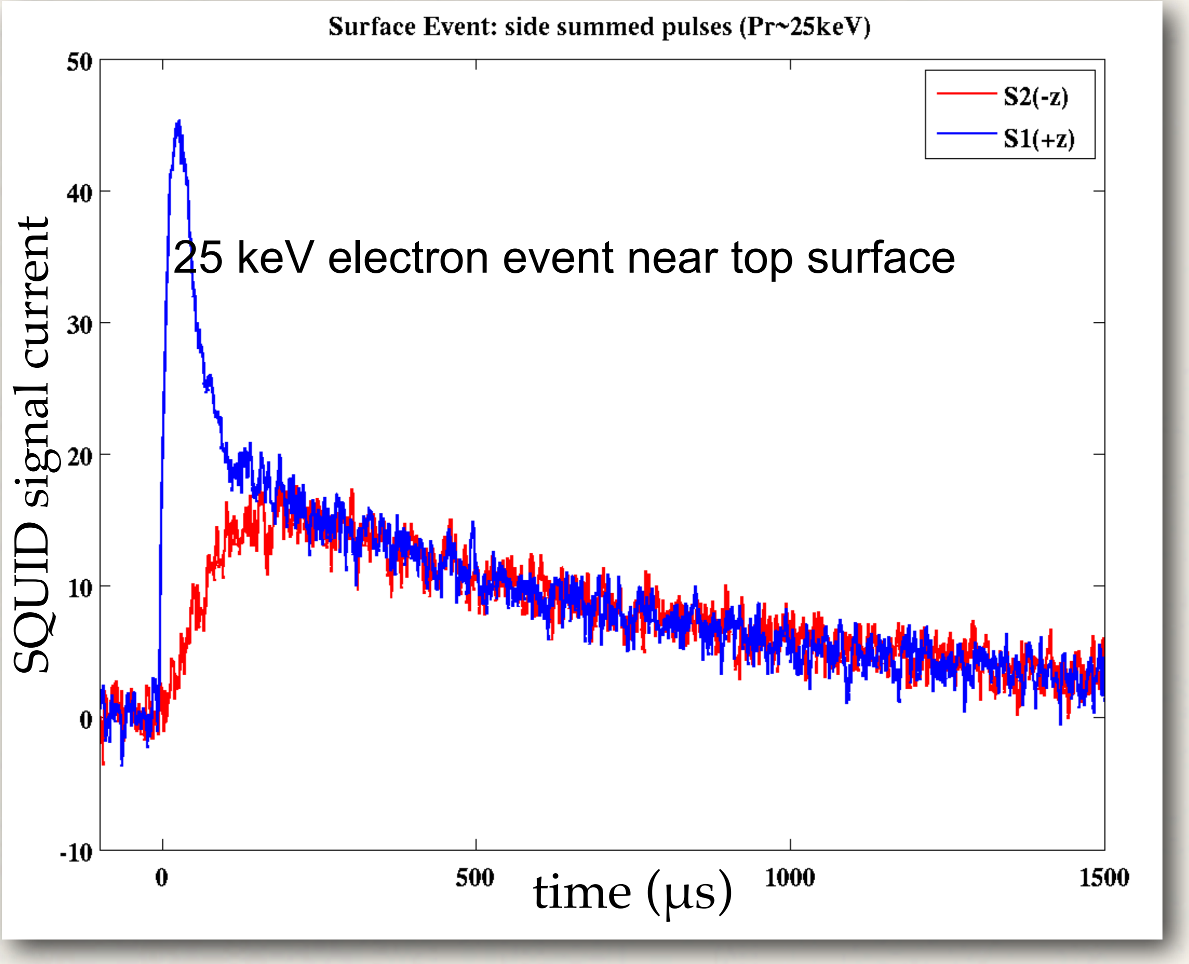
SuperCDMS Soudan: ^{210}Pb Test

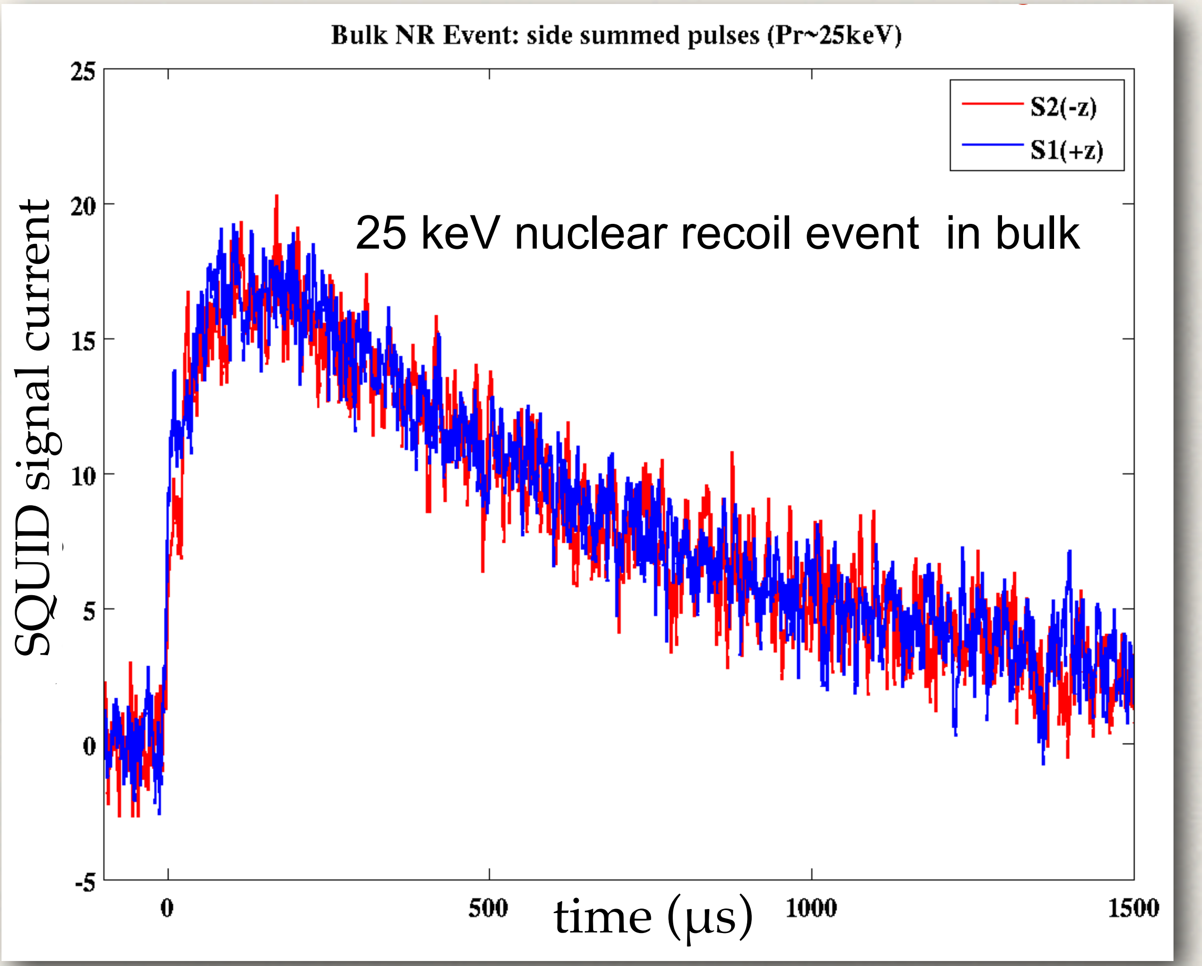




- March - July 2012: ~65,000 electrons and ~15,000 ^{206}Pb recoil surface event collected from ^{210}Pb source.
- 0 events leaking into the signal region (< 2.5 x 10^{-5} @90% C.L. misID)
- 63% fiducial volume (8-100 keVnr)
- Good enough for a 200 kg experiment run for 4 years at SNOLAB!

SuperCDMS iZIP: Phonon Signal

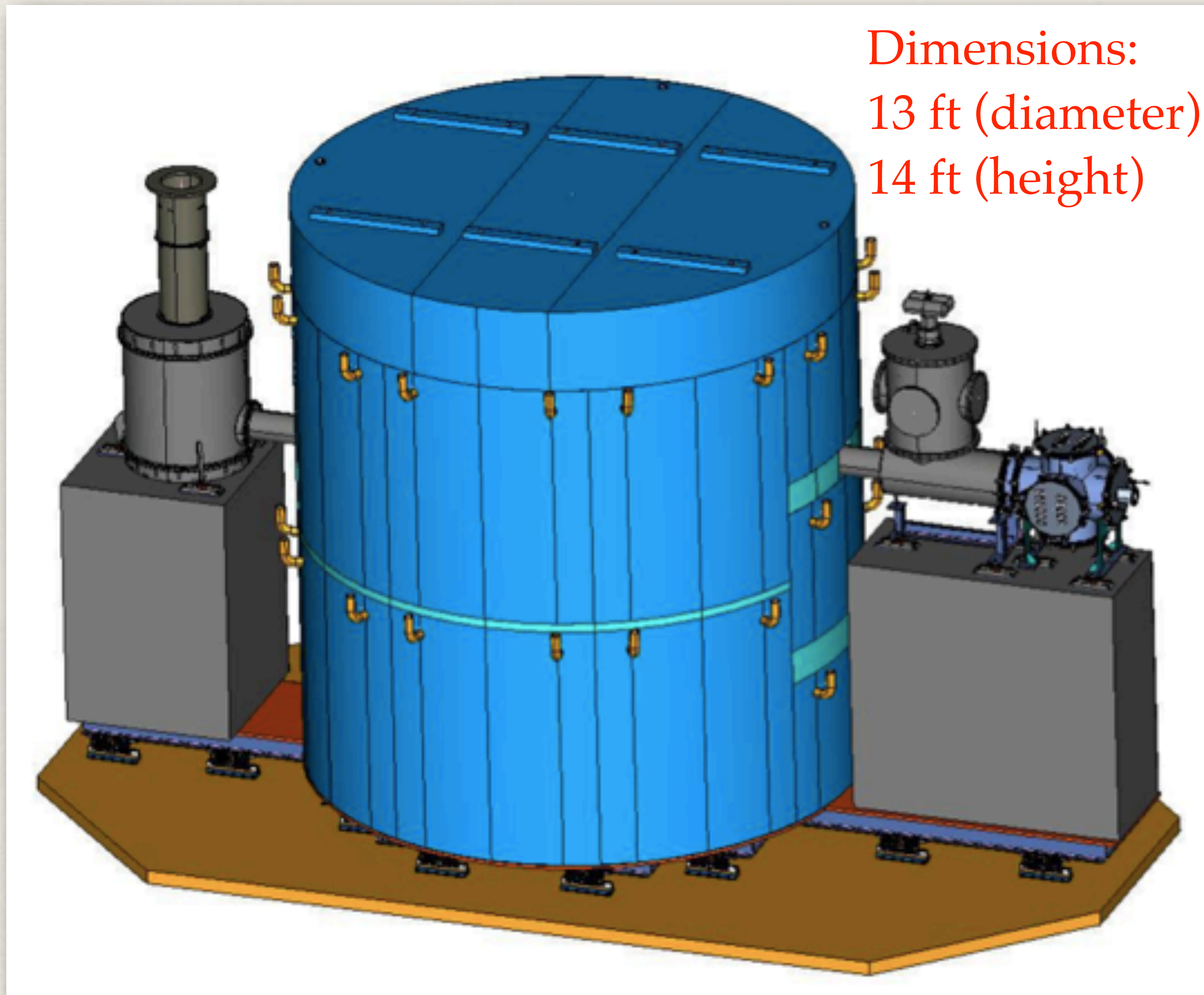




- Phonon timing pulse information still possible.
  - Surface electron vs bulk nuclear recoil event discrimination
- PULSE SHAPE HAS NOT YET BEEN USED! (It's not needed.)

SuperCDMS SNOLAB: G2 Experiment at the Ladder Lab

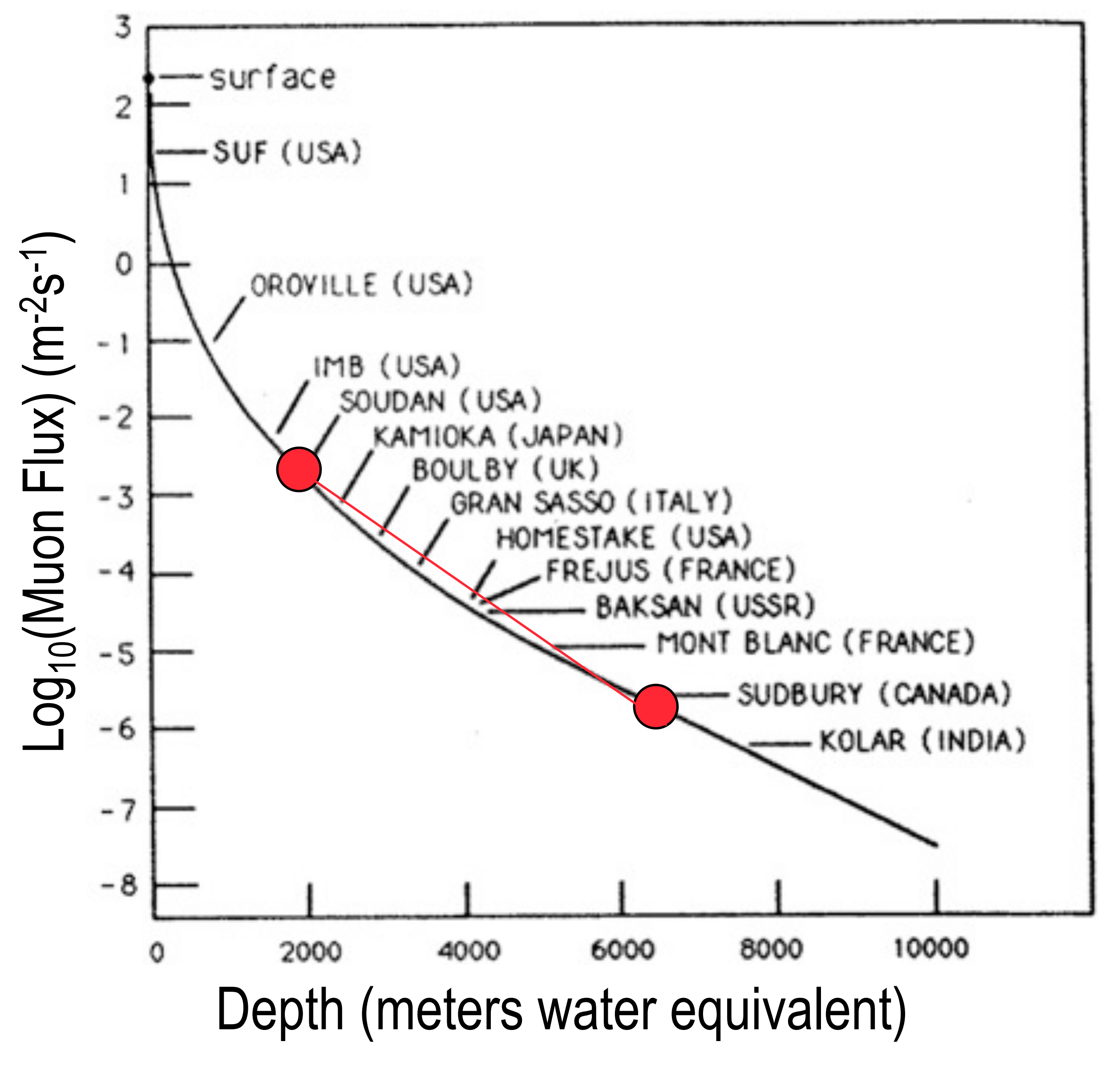
SuperCDMS at SNOLAB



Planned Setup

- cryostat volume of up to 400 kg target
  - 200 kg experiment with sensitivity of 8×10^{-47} cm^2 at 60 GeV/c^2
- Pb/Cu shielding for external radiation
- increased PE shielding (neutrons)
- possible neutron veto

Why SNOLAB?
Depth is Important



Soudan

2090 mwe

0.05 n/y/kg

SNOLab

6060 mwe

0.2 n/y/ton

(0.0002 n/y/kg)

- Only need to worry about radiogenic neutrons!

Radiogenic Neutrons

- External Radiogenic Neutrons
  - Resulting from fission and alpha-n interactions from U, Th in cavern rock
  - Expected to be negligible with passive shielding
- Internal Radiogenic Neutrons
  - Resulting from fission and alpha-n interactions from U, Th in copper cans, shielding and supports.
  - Expected to be ~1 event, depending on material cleanliness

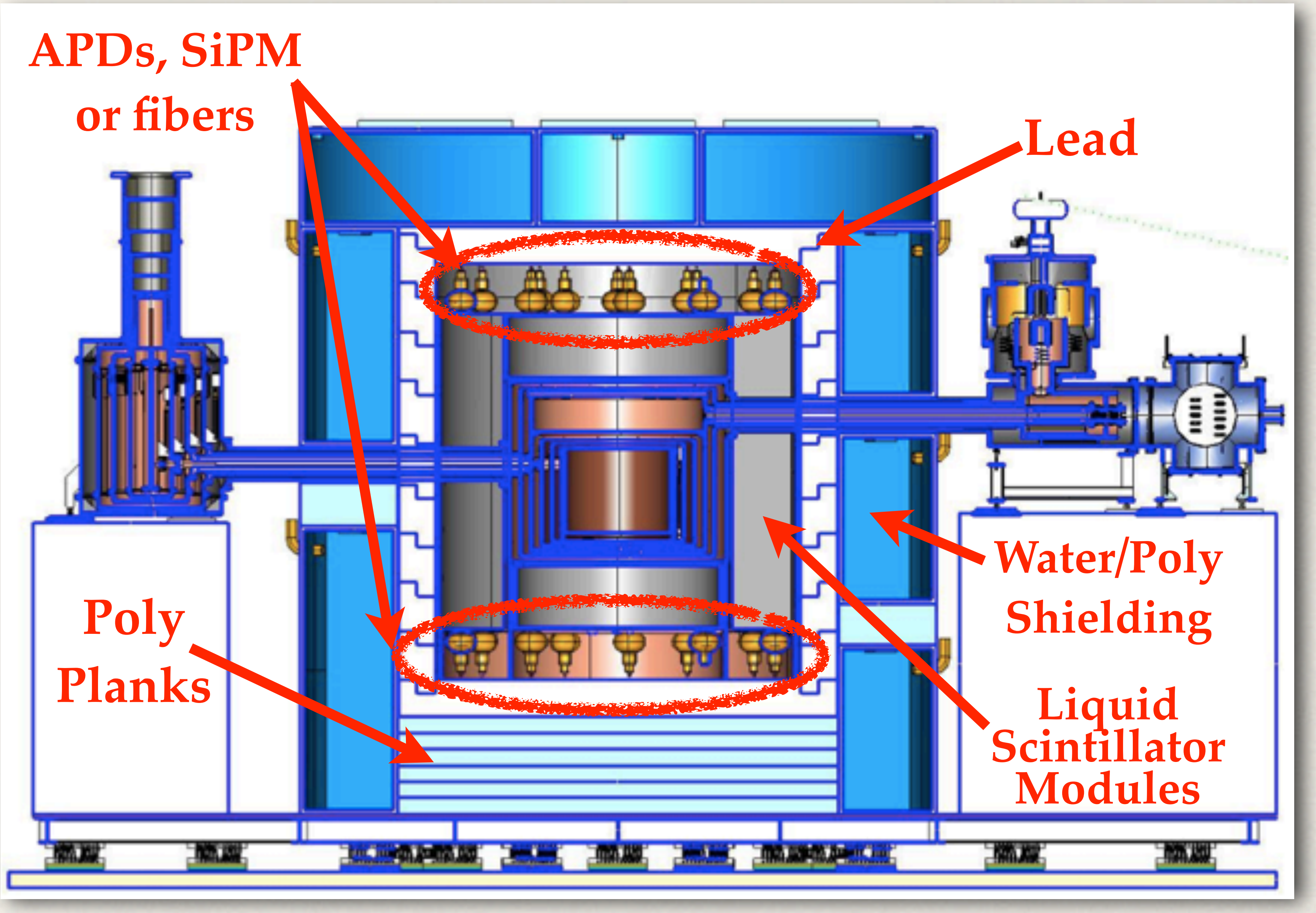
For these reasons we are considering a neutron veto in the shield design.

Physics Requirements for a Neutron Veto

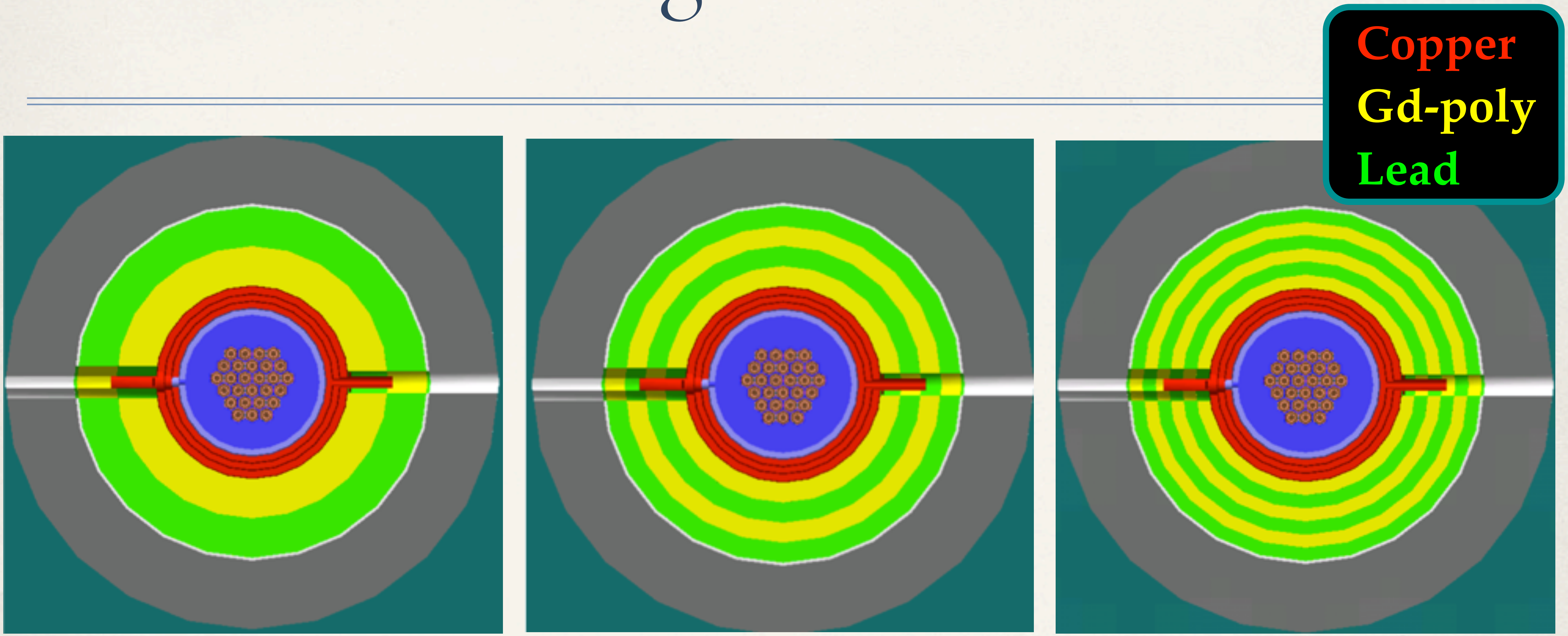
- Total unvetoed background in iZIP detectors: < 1 event in the 200 kg phase.
- Total background rate (gamma + neutrons) must not generate excessive background rates in the iZIP detectors
    - Implies radio-clean construction
- Negligible contribution to dead-time
    - Implies low (<kHz) non-coincident trigger rate
- High efficiency to detect neutron capture
    - Aim for 90% or better

Design Details

- Surround the cryostat with a high efficiency neutron detector to tag neutrons.
- Modular tanks of liquid scintillator, with radial thickness 0.4 m, viewed by phototubes.
  - Details of scintillator to use (Gd or B loaded) under consideration.



Alternate Design



- Alternating layers of Gd-loaded poly/scintillator and lead.
- Preliminary studies underway.

Summary

- SuperCDMS at Soudan (~9 kg) is taking data with iZIP detectors and expects to reach a WIMP-nucleon sensitivity of 2 x 10^{-45} cm^2 for spin-independent interactions.
- We have demonstrated surface event rejection with the new iZIP detector design using ^{210}Pb sources which paves the way for better than 10^{-46} cm^2 sensitivity at SNOLAB.
- Ongoing studies are assessing the necessity and feasibility of including a neutron veto in the SuperCDMS at SNOLAB design.